NATIONAL BUREAU OF STANDARDS

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U.S. DEPARTMENT OF COMMERCE

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Technical News Bulletin

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COVER

Lower portion of the apparatus used to measure the acceleration of gravity. Counterweights hold carriage in intermediate position while Douglas Tate makes adjustments. *(See page 50.)*

U.S. DEPARTMENT OF COMMERCE
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The National Bureau of Standards serves as a focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. For this purpose, the Bureau is organized into three institutes—
- The Institute for Basic Standards
- The Institute for Materials Research
- The Institute for Applied Technology

The TECHNICAL NEWS BULLETIN is published to keep science and industry informed regarding the technical programs, accomplishments, and activities of all three institutes.

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LINE-STANDARD INTERFEROMETER

For Accurate Calibration of Length Scales

Accurate calibration of length scales at moderate cost is made possible by an automatic fringe-counting interferometer developed at the National Bureau of Standards. Using light waves from a laser source, the instrument measures line standards directly in lengths up to 1 meter and achieves a precision of a few parts in 10^8.

The line-standard interferometer[1] was devised by H. D. Cook and evaluated by J. S. Beers as part of a program for the automation of NBS calibration activities. It has already reduced the time required for length-scale calibrations by a factor of 10, with a corresponding reduction in costs.[2]

Graduated length scales are used to define translation distance in many types of precision machine tools and scientific instruments. Heretofore their calibration has been laborious, sometimes requiring thousands of visual microscope comparisons. Thus until now calibration costs have been so prohibitive that few adequately calibrated length scales existed outside the national standards laboratories of the more highly industrialized nations.

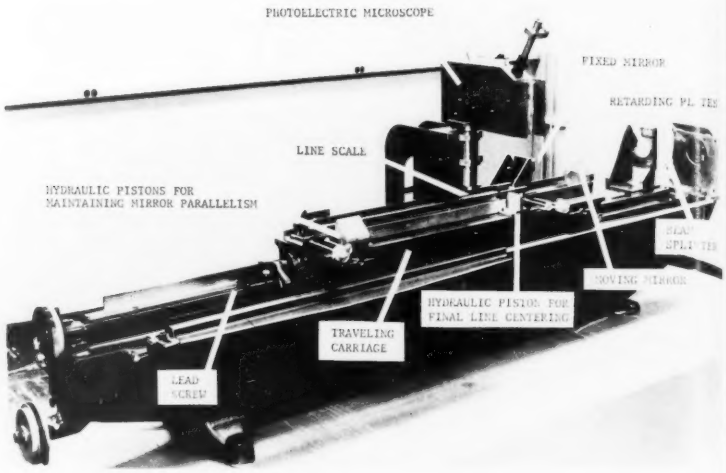
Design and Operation

The basic parts of the instrument are an interferometer for establishing an accurate length standard, an automatic photoelectric microscope for line positioning, environmental controls, and data recording and processing equipment.

The main body of the calibrator is a precision way bed, 2 meters long, on which a carriage holding the length scale is moved by a lead screw. A modified Michelson interferometer is mounted at one end of the bed with one of its plane mirrors attached to the movable carriage. The photoelectric microscope is mounted above the carriage in a fixed position to scan all scale graduations as the carriage moves. This entire apparatus is in a vibration isolated enclosure held at 20 $\pm$0.01 °C by a servo-controlled circulating water bath. All heat producing components such as light source, photomultiplier tubes, microscope lamp, drive motor, and electronic circuits are externally mounted. Room temperature is maintained at 20 $\pm$0.25 °C.

Fringes formed by the interferometer are detected, counted, and interpolated, giving a continuous indication of carriage position. Using plane mirrors in the interferometer instead of the more common retroreflectors is an important feature, allowing servo-controlled alinement of the scale and other parts and reducing possible geometric measurement errors. Four retarding plates divide the interferometer beam into quadrants and the plates are adjusted to produce a 90° phase displacement between patterns in adjacent quadrants. When the carriage moves, four sinusoidal signals are obtained from photomultipliers monitoring each quadrant. Fringe counting, fringe interpolation, and servo-control of mirror parallelism are derived from these four related signals.

J. S. Beers observes the monitor and control panel of the line-standard interferometer during an automatic calibration of a length scale. A graduation line is electronically shown (upper left) while the fringe count to the nearest hundredth is displayed (lower).



The way bed and movable carriage of the line-standard interferometer developed at NBS are shown before the apparatus was installed in its temperature-controlled housing. The photoelectric microscope views the graduations on a length scale placed in the carriage. Carriage displacements are made to correspond exactly to scale length intervals by centering each graduation mark in the microscope 's optical axis. The laser beam enters behind the beam splitter, and fringe detecting photomultipliers are mounted to the left of the beam splitter.

LINE-STANDARD *continued*

The stabilized laser (helium-neon) light source has greatly improved the interferometer's range. Coherence of laser light exceeds that of other light, and high contrast interference fringes are easily maintained over the meter-long path. With other light sources scales longer than 2 decimeters had to be measured in steps and the results added to obtain a full calibration.

Length scale calibration is achieved by making carriage displacement correspond exactly to scale interval length. This correlation is accomplished by the photoelectric microscope. A vibrating mirror in the microscope sweeps a magnified image of the vertically illuminated graduation across a slit located in front of a phototube. Electronic circuits analyze the resulting signal and generate an output voltage proportional to the deviation between line center and microscope field center. When this voltage is zero the line is centered, and the interferometer fringe count is recorded.

Temperature Control

Temperature control is important because it affects the wavelength of light, the length of the scale, and the critical orientation of interferometer mirrors and microscope. Automatic recording thermocouples monitor temperature at 10 points inside the interferometer housing. Signals from the thermocouples are averaged or used individually for servo-control of the water bath temperature circulating in the interferometer housing. The reference themocouple junction is maintained at 20 °C as indicated by a platinum-resistance thermometer.

Use in Calibration

After the scale is mounted, interferometer alined, and temperature equalized, the carriage is set so that the zero scale graduation is in the microscope field. The servo-control makes the fine adjustment of the carriage, centering the graduation. The arbitrary reference fringe count is automatically recorded. The lead screw immediately drives the carriage to the next programed stop, placing the graduation within the microscope field. The servo again makes the fine adjustment, centering the graduation. Fringes are counted during motion of the carriage and the total count is recorded to the nearest hundredth of a fringe as soon as centering occurs. This automatic procedure is repeated until the terminal graduation is reached. For increased accuracy the scale is then measured in the opposite direction.

The limitations on the size of scales that can be calibrated in this instrument are: length, 1 meter; width, 100 millimeters; and thickness, 50 millimeters. The segment of each graduation to be calibrated should be defined by a pair of longitudinal lines spaced 0.1 or 0.2 mm apart, running the length of the scale. Graduation width should be 25 microns or less.

Data Processing

The refractive index of air, and consequently the wavelength of light, are affected by atmospheric pressure, temperature, and humidity. These parameters, plus the temperature of the scale and the fringe counts recorded at each scale graduation, are fed to a digital computer. The computer makes all the necessary corrections and prints the final results in tabular form showing the length of each measured scale interval. A statistical analysis comparing and averaging the results of several passes on the same scale is also possible.

Accuracy

Calibration accuracy is limited by scale graduation quality, microscope sensitivity, accuracy of temperature control, and measurement uncertainty of the wavelength of the laser light and other factors. The small uncertainty of the laser wavelength is not a serious limitation as present length-scale calibration accuracy is five parts in 10^7, and the wavelength uncertainty is only a few parts in 10^8.

The line-standard interferometer was tested for accuracy by measuring NBS reference meter bars. Thus the

interferometer was compared with conventional methods of measuring length scales and was found to be at least as accurate. It has therefore been put into routine operation with the same calibration accuracies offered as were previously available: ±1 micron (±0.000040 inch) and ±0.5 micron (±0.000020 inch).

Experiments are under way to apply the line standard interferometer to the calibration of long gage blocks and step gages. Preliminary results have been so encouraging that it is hoped this new service can be offered in the near future.

[1] For further details, see **Use of a laser for length measurement by fringe counting**, by K. E. Gillilland, H. D. Cook, and K. D. Mielenz, Metrologia, **2**, 95–98 (July 1966).

[2] For a schedule of calibration fees, see NBS Misc. Pub. 250, Calibration and test services of the National Bureau of Standards, 1965 edition. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for $1.00

CONFERENCE BRIEFS

AAAS SESSION HELD AT NBS

As part of the 133d meeting of the American Association for the Advancement of Science, the 8th Washington Session of Section B—Physics, was held at the Bureau's Gaithersburg site on Thursday, December 29, 1966. The session included four invited papers on physical measurement and data systems, the Section B vice-presidential address, and a tour of the new NBS facilities.

R. D. Huntoon, Director of the Institute for Basic Standards, introduced the systems approach as a new way of looking at the vast complex of measurement activities in broad perspective, to evaluate the effectiveness of the overall system and its various elements, and to take whatever action is necessary to improve the system's operation and output. Such an approach should lead to more accurate measurement throughout the Nation and to the more rapid advancement of science and technology, which are based on measurement. Dr. Huntoon said the role of NBS in this system is to provide the central core of natonal standards and to supply central Federal leadership for it.

L. E. Howlett (Director of the Division of Applied Physics, National Research Council, Canada; and Chairman of the International Committee of Weights and Measures) explained the work of the International Bureau of Weights and Measures (IBWM). The IBWM provides a world measurement system that is uniform everywhere and of high accuracy and precision, without which there would be no scientific and industrial progress. The IBWM's responsibility is to set up "points of departure" for measurement research. Such work takes in the improvement, refinement, or replacement of the six basic units (meter, kilogram, second, ampere, degree kelvin, and candela). It also covers areas in which the lack of departure points prohibits even the best scientists from attaining the desired precision, accuracy, and uniformity.

E. L. Brady, Chief of the NBS Office of Standard Reference Data, spoke on the activities of the "National Standard Reference Data System" and its role in the national measurement system. NSRDS was established in 1963 as an attempt to provide the scientific and technical communities with critically evaluated scientific data by creating a storehouse of standard reference data. In the past 3 years, significant progress has been made in setting up data evaluation and compilation projects throughout the country, particularly in the fields of thermodynamic and transport properties and in atomic and molecular properties.

H. Brown, of the California Institute of Technology and Foreign Secretary of the National Academy of Sciences, discussed the international aspect of data compilation. He reviewed the founding last year of the Committee on Data for Science and Technology (CODATA) which is sponsored by the International Council of Scientific Unions. In general, CODATA's goals are to improve compilation efforts by increased participation of young scientists, better working conditions and facilities for compilers, increased budgets for such work, and by encouraging experimental research to fill the gaps in both the knowledge and compilations in important areas.

A. V. Astin, NBS Director and vice president of Section B, described the Bureau's efforts in planning its new laboratories at Gaithersburg. He explained the reasons for relocating the Bureau and the problems involved in designing an ultramodern research facility which would meet the various needs of over 1,000 scientists and engineers working in the physical sciences.

The attendees then toured the new facilities including the Bureau's linear particle accelerator, a helium-neon laser used for length measurement, equipment for measuring forces up to 12 million pounds, some of the basic electrical standards, and a display of some of the varied work in materials science performed at NBS.

SYMPOSIUM ON CERAMIC MATERIALS AND THEIR PROPERTIES

A total of 140 scientists and engineers attended a 1-day symposium on ceramic materials and their properties on October 14, 1966. The symposium was held at the new

continued

CONFERENCE BRIEFS *continued*

site of the National Bureau of Standards in Gaithersburg, Md. The symposium was jointly sponsored by the American Ceramic Society, the American Society for Testing and Materials, and the National Bureau of Standards.

Intended primarily for engineers and scientists whose specialties are in fields other than ceramics, the symposium provided a concise introduction to the properties of ceramic materials somewhat in the manner of a short course. The papers presented were also preprinted and distributed to the symposium attendees.

As an introduction, Cyrus Klingsburg of the National Academy of Sciences spoke on the scope of modern ceramic materials. He set the stage for the other papers by tracing the use of ceramics from the dawn of history to the present. He pointed out that while the field of ceramics is still an art form today, it is also both an engineering technology and a science in our modern society.

H. F. McMurdy of ASTM went into the crystal chemistry of ceramics dealing with the formation of compounds, their atomic structure, and their isostructural, isomorphous, and polymorphic relationship. He related these factors to the properties which make these materials useful in various applications. J. F. Schairer of the Geophysical Laboratory, Carnegie Institute of Washington, explained the usefulness of phase equilibrium diagrams to determine the thermal behavior of ceramic materials.

L. P. Domingues of the Bureau of Mines discussed the thermal properties of ceramics from the standpoint of the effect of temperature on the vibrations of the lattice of constituent atoms or ions comprising the ceramics. F. J. Mardulier, ASTM vice president, addressed the symposium on the value of ASTM to the ceramics industry and pointed out the need for increased standardization. J. B. Wachtman, Jr., of NBS spoke on the mechanical properties of ceramics and how these usually result from interactions of fundamental deformation processes. J. L. Pentecost of Melpar, Inc., covered the general nature of ceramic materials used for electrical applications.

The papers on crystal chemistry and mechanical properties will be published by the American Ceramic Society in its Bulletin; those on thermal properties and electrical properties will be published by Industrial and Engineering Chemistry.

A followup symposium on the properties of ceramic materials is planned for the spring of 1968. Information concerning this symposium can be obtained from Dr. J. B. Wachtman, Jr., Inorganic Materials Division, National Bureau of Standards, Washington, D.C. 20234.

NBS HOSTS AWS AND ASM REGIONAL MEETING

Approximately 175 members of the American Society of Metals and the American Welding Society held a joint regional meeting at the National Bureau of Standards' new Gaithersburg (Md.) laboratories on Friday, December 9, 1966. The program included talks by NBS staff members and a tour of selected laboratories to better acquaint the societies with the Bureau's role in materials research and measurement standards.

The morning session began with a welcoming address by A. V. Astin, NBS Director. The next speaker was H. E. Sorrows, Assistant to the Director of the Institute for Materials Research, who gave a presentation on the organization and programs of IMR. M. R. Meyerson, Chief of the Engineering Metallurgy Section, then spoke on the organization and programs of the Metallurgy division. W. W. Meinke, Chief of the Analytical Chemistry Division and the Office of Standard Reference Materials, followed with a discussion of NBS work in standard reference materials and analytical chemistry.

The visitors were also given a description of some of the Bureau's new large force-measurement facilities and their uses, by L. K. Irwin, Chief of the Engineering Mechanics Section. C. O. Muelhause then discussed the Bureau's new reactor facility and its applications. The talks were concluded by R. S. Caswell, Acting Chief, Radiation Physics Division, speaking on NBS facilities and programs for the study of ionizing radiations.

The afternoon tour of NBS laboratories included a display of representative outputs of the Institute for Materials Research illustrating the great variety of programs it carries out in materials science. The visitors saw a heat treating laboratory which was equipped for treating metals in vacuum, endothermic atmosphere, cracked ammonia, hydrogen, helium, argon, and nitrogen at temperatures up to 2400 °F. They also visited the Engineering Mechanics Building which houses a 12-million-pound-capacity testing machine used for testing large structural components and devices such as those used to measure rocket thrust.

The visitors were shown the procedure for preparation, certification, and distribution of standard reference materials. Standard reference materials fill the needs of industry, science, and Government for reliable reference points in the Nation's measurement system.

Also included in the tour was the NBS 10-megawatt research reactor. This facility will supply radiation for studies of molecular and crystalline structures, investigations of nuclear processes such as fission and neutron capture, standards development, and generation of radioisotopes for activation analysis and tracer production.

The final part of the tour included a trip through the new Central Instrument Shops where the society members observed applications of new techniques in the design and fabrication of joints for ultrahigh vacuum systems components.

These processes included semi-automatic T.I.G. welding, vacuum electron beam welding, vacuum furnace brazing, and the application of vacuum leak detector testing.

Clamp for Low Temperature Experiments

Left: The fingers of the Dewar clamp made at NBS are lined with cork strips and are tightened on a Dewar neck by the surrounding aircraft-type hose clamp.
Right: W. J. McKean places a Dewar flask, held by the clamp he made, into a nuclear magnetic resonance spectrometer. The clamp has proved quite useful in this apparatus.

The support of large, expensive, and complicated glass Dewars in a safe and convenient way is a major problem in building experimental low temperature apparatus. To solve this problem for researchers in the NBS Institute for Materials Research, W. J. McKean, an instrument maker assigned to the solid state physics laboratory, has made a Dewar clamp that offers ease of installation on the cylindrical Dewar neck.

A commercial Dewar clamp usually fits only the Dewar with which it is sold, and the clamp is not easily converted for different experimental arrangements. Also, many commercial clamps are constructed in such a way that nonuniform stresses are placed on the glass Dewar neck. The NBS-built Dewar clamp, however, eliminates these disadvantages and can be inexpensively constructed in laboratory workshops.

This Dewar clamp consists of a cylindrical sleeve which has been slotted to provide a number of fingers around the cylinder wall. Strips of cork are cemented on the inside surface of these fingers to grip the Dewar, and the fingers are tightened uniformly on the Dewar neck by adjustable aircraft-type hose clamps. A flange around the bottom of the cylindrical clamp holds the entire assembly on a support table. This flange is about one-half inch in width and can be marked accurately in angular increments so that the Dewar apparatus can be rotated through certain angles as desired. The clamp is made of aluminum, and the inside cylindrical dimensions can be machined to fit any Dewar.

NEW TUNGSTEN-FILAMENT LAMP STANDARDS ADOPTED

A great deal of time, effort, and money are being expended today to obtain measurements of solar radiation in space. These measurements, as well as those required in studies of photochemical processes, have brought about a need for higher accuracy and wider ranges in measurements of total irradiance than were previously required.

To obtain more accurate radiation measurement, R. Stair, W. E. Schneider, and W. B. Fussell of the NBS Institute for Basic Standards recently made a study which has led NBS to adopt new standards of total irradiance. This study, supported by the National Aeronautics and Space Administration, showed that tungsten-filament lamps are more accurate, are available in a wider range of output, and can be operated at higher temperatures than the previous carbon-filament lamp standards.

Most of the meteorological measurements of solar radiation throughout the world are still based on the Angstrom-type pyrheliometer or the Abbot silver-disk instrument. However, neither of these instruments can be considered truly absolute and through the years differences in results have occurred through the use of the two instruments. To date, differences between the two scales (1 to 2 percent) have not been completely resolved; thus a new standard has been needed in this area.

For other than meteorological measurements, a standard of total irradiance originally set up by Coblentz [1] in 1913 was the 50-watt carbon-filament lamp operating at a color temperature of 1800 to 2000 °K. This standard has served well for more than 50 years in the United States and throughout the world. However, the new standards operate at much higher temperatures than the carbon-filament lamps and the peak of their spectral energy curve falls more toward the shorter wavelengths. This curve conforms more closely to the spectral curves of the NBS

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STANDARDS AND CALIBRATION

PULSE VOLTAGE CALIBRATION SERVICE

A new calibration service for peak pulse voltage is now being offered by the Radio Standards Laboratory (Boulder, Colo.) of the NBS Institute for Basic Standards.

Measurement capabilities are in the range of 5 to 1,000 volts peak. From 5 to 100 volts the rise time of the measured pulse can be as fast as 10 nanoseconds, and the peak duration as short as 10 nanoseconds. The maximum pulse duration in this lower voltage range is limited to 100 microseconds with a duty factor of 0.10 or less. In the range of 100 to 1,000 volts, measurements can be made on pulses having rise times as fast as 30 nanoseconds and peak durations of 30 nanoseconds or more. Maximum pulse duration in the higher voltage range is limited to 5 microseconds with a duty factor of 0.01 or less.

Pulse duration, as used here, refers to the time the pulse amplitude is greater than 50 percent of peak amplitude. Peak duration is defined here as the time that the pulse is at peak amplitude or greater than 99.8 percent of the peak amplitude.

The uncertainty of measurement over the range of 5 to 1,000 volts is 1 percent.

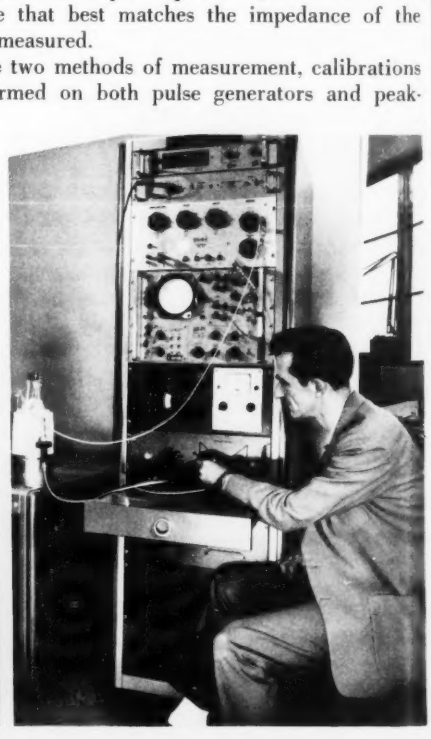
The method of measurement utilizes two independent systems that can be intercompared, one a standard pulse generator, the other a peak pulse voltmeter. The standard pulse generator consists of a group of Zener diode limiting circuits that are driven by pulse amplifiers and commercially available pulse sources. Several types of Zener circuits have been developed, some of which are for fast risetime pulses.

A d-c measurement affords an easy and accurate method of determining the limiting voltage of the Zener diode circuits. To avoid unwanted heating effects caused by the use of dc to calibrate low duty cycle pulses, the diodes are immersed in liquid nitrogen. In this way their temperature can be held constant over wide extremes of operation, and any effect of temperature variation on the limiting voltage is removed. Furthermore, any instabilities caused by room temperature variations are also avoided.

The voltmeter is a slideback circuit arrangement in which a voltage pulse of unknown amplitude is compared against a d-c voltage. Nulling of the voltage pulse with an accurately measured d-c voltage gives the peak pulse voltage.

The slideback voltmeter is constructed with a coaxially mounted input in which the pulse is nulled, so that the pulse is not affected by coaxial leads or wiring beyond the input section. Several input sections have been constructed with different input impedances, so that one can select the one that best matches the impedance of the system being measured.

Using these two methods of measurement, calibrations can be performed on both pulse generators and peak-



Leon F. Saulsbery of the Radio Standards Laboratory making adjustments to intercompare the slideback voltmeter with the Zener diode limiting circuits located in the Dewar flask at the left. The equipment is used in the calibrating peak pulse voltage.

Zener diode limiting circuits and Dewar flask containing liquid nitrogen in which Zener circuits are immersed for temperature stabilization.

reading pulse voltmeters. It is expected that manufacturers of pulse voltage equipment, such as generators and voltmeters, will find this service useful. Groups using voltage pulse equipment, such as those involved in computers, radar, telemetry, and medical electronics, should find the service helpful in determining equipment accuracy and in maintaining compatibility with the national measurement system.

It is anticipated that a calibration service at higher voltages will become available, and that the uncertainty of measurement in the present range will be reduced.

EFFECTIVE EFFICIENCY OF COAXIAL BOLOMETER UNITS

From 4 to 10 GHz

The Radio Standards Laboratory (Boulder, Colo.) of the NBS Institute for Basic Standards announces a calibration service for the measurement of effective efficiency [1] of coaxial bolometer units over a continuous frequency range from 4 to 10 GHz. In this range the calibration service was available previously only at 9 GHz.

This extension of the service is based on a measurement technique developed by Glenn F. Engen [2] of the Radio Standards Engineering Division. The technique provides a means of transferring the calibrations of bolometer units in rectangular waveguide systems to coaxial bolometer units. This is done with the aid of a coaxial-to-waveguide transition.

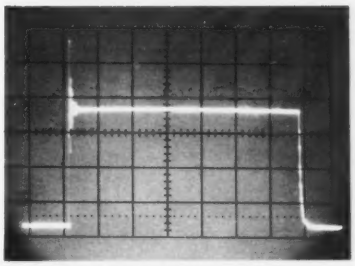
Although a transfer is made from one type of transmission line to another, the uncertainty in the effective efficiency of the coaxial unit eventually measured is reasonably low. In the frequency range of 7.05 to 10 GHz the estimated limit of error is 1.5 percent, and in the frequency range of 4 to 7.05 GHz the estimated limit of error is 2 percent.

The calibration service is available at present only for the measurement of effective efficiency and at a nominal power of 10 milliwatts. The bolometer unit must be fitted with a male Type N connector complying with MIL–C–39012 specification; and it must contain thermistor-type elements having a nominal operating resistance of 200 ohms.

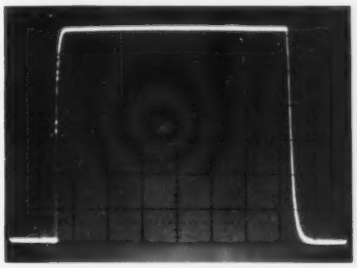
STANDARD FREQUENCY AND TIME BROADCASTS

WWV—2.5, 5.0, 10.0, 15.0, 20.0, and 25.0 MHz
WWVH—2.5, 5.0, 10.0, and 15.0 MHz
WWVB—60 kHz

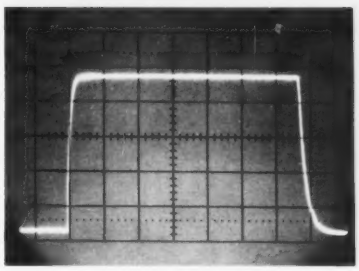
Radio stations WWV (Fort Collins, Colo.) and WWVH (Maui, Hawaii) broadcast signals that are kept in close agreement with the UT2 scale by making step adjustments of 100 ms as necessary. Each pulse indicates that the earth has rotated approximately 15 arcseconds about its axis since the previous one. Adjustments are made at 0000 UT (7:00 p.m., e.s.t.) on the first day of a month.



Input pulse to Zener diode limiting circuit. Sensitivity of oscilloscope 200 volts per division. Sweep speed set at 1 μsec per division.



Output pulse from a 600-volt Zener limiting circuit driven by input pulse shown in top photograph. Vertical sensitivity of oscilloscope 100 volts per division.



Output pulse from a 400-volt Zener limiting circuit driven by input pulse shown in top photograph. Vertical sensitivity of oscilloscope 100 volts per division.

There will be no adjustment made on 1 April 1967. The pulses occur at intervals that are longer than 1 second by 300 parts in 10^{10} due to an offset in carrier frequency coordinated by the Bureau International de l'Heure (BIH), Paris, France.

Radio station WWVB (Fort Collins, Colo.) broadcasts seconds pulses derived from the NBS Time Standard (NBS–III) with no offset. Step adjustments of 200 ms are made at 0000 UT on the first day of a month when necessary. BIH announces when such adjustments should be made in the scale to maintain the seconds pulses within about 100 ms of UT2. There will be no adjustment made on 1 April 1967.

[1] The effective efficiency of a bolometer unit is the ratio of substituted d-c power in the bolometer unit to the rf power dissipated within the unit.

[2] Coaxial power meter calibration using a waveguide standard, by G. F. Engen, J. Res. NBS 70C (Engr. &. Instr.), 127 (Apr.–June 1966).

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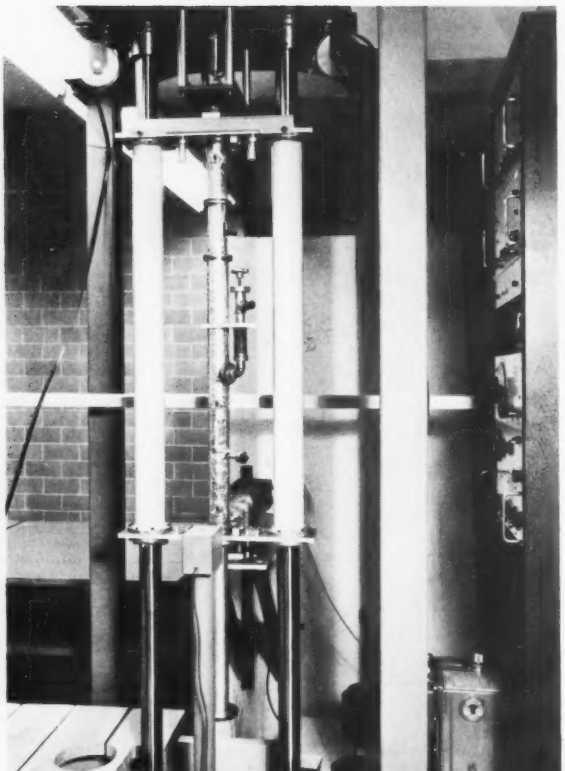


Apparatus used recently to determine the acceleration of gravity.

A new absolute determination of the acceleration due to gravity (g) has been made by the National Bureau of Standards. The measurement was made at the Bureau's laboratories near Gaithersburg, Md., by Douglas R. Tate of the NBS Institute for Basic Standards.[1]

The result, reduced to a gravity meter station on the floor of the site, is 9.801018 m/s^2 with a standard deviation of $\pm 0.3 \times 10^{-5}$ m/s^2 ($= \pm 0.3$ milligal).[2]

The acceleration due to gravity is a pivotal quantity in several areas of precise measurement. It enters directly into the NBS determination of the ampere as an electrical standard, into standards of force for calibrating load cells that measure rocket thrust, and into standards of fluid pressure (where it is needed, for example, to express in terms of the meter, kilogram, and second the pull of gravity on the mercury in a precision barometer).

Geodesists studying the size and shape of the earth are especially interested in how g varies from one place to another, since this tells them something about the way the earth's mass is distributed. It happens also that the difference between the values of g at two places can be measured more accurately (to ± 0.01 milligal in the best determinations) than can the absolute values themselves. Geodesists have therefore, since 1909, adopted a particular site in Potsdam, Germany, as a conventional reference point; assigning it the value of g obtained in 1906 by Kühnen and Furtwängler, and assigning values to other places by adding to this the measured change in g when one goes from Potsdam to the place in question. Later absolute determinations have shown that the absolute values assigned on the Potsdam system are too large. Thus the absolute value of g obtained in the present measurement at NBS is 13.2 milligals below its Potsdam value, a result that agrees well with other recent determinations.

ACCELERATION DUE TO GRAVITY MEASURED AT NBS

The Method Used

Like other recent precise determinations of g, except those employing the Kater reversible pendulum principles, the new NBS experiment involves time and distance measurements on a freely falling body. In this case, the body is a hollow rod of fused silica about 1.3 cm in diameter and 103 cm in length, which falls with its long axis vertical.

In the rod are three holes whose lower edges are bounded by carefully made knife edges of metal. These edges are mounted perpendicularly to the long axis, one near the lower end of the rod, one about 30 cm above the first, and the third about 70 cm above the second. The critical distances are those between the first and second knife edges (about 30 cm) and between the second and third knife edges (about 70 cm). The critical times are those required for the rod to fall through the two critical distances.

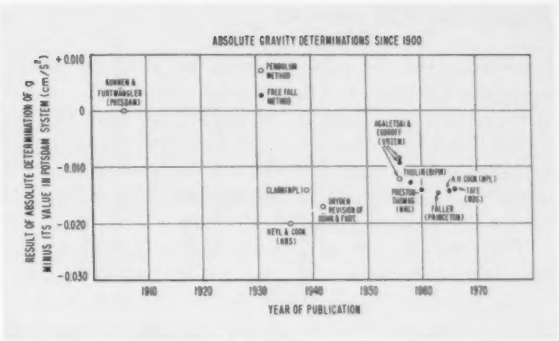
If each critical distance is divided by its corresponding time, one obtains the average downward speeds for two immediately successive intervals. From these the value of g is obtained by a simple calculation.

The distances between the knife edges are found by comparison with an invar line standard mounted on the g-apparatus. The invar standard is checked in turn against a group of standards the values of which are derived from the wavelength standard of length.

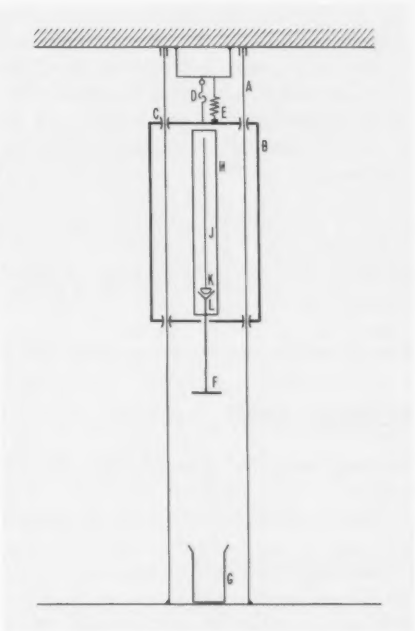
Timing is done with the help of a collimated light beam, a photomultiplier cell, and two electronic timers. As the rod falls, it interrupts the beam of light, preventing it from reaching the photocell. However, when the first (lowest) knife edge reaches the beam, light begins to pass through the adjacent hole and the resulting signal from the photocell sets the two electronic timers going. A little later the second metal edge reaches the beam and again the light falls momentarily on the photocell, and this time the electrical signal from the photocell is used to stop the first timer. Finally, when the third metal edge reaches the beam, the pulse from the photocell stops the second timer. The first of the required times is then simply the reading of the first timer, and the second required time is the difference between the two timer readings. Timer accuracy is checked against the NBS frequency signals which are derived from the atomic frequency standard.

A feature of the method is that the silica rod is enclosed in a vacuum chamber which falls together with it. The chamber is mounted on a carriage, and it has three pairs of windows (front and back) opposite the holes in the rod to let the light beam through.

The falling chamber technique has the advantage that any air remaining in the chamber is very nearly at rest with respect to the falling rod, so that the frictional drag on the rod is minimized. Consequently, only a moderate vacuum is needed.



Absolute determinations of the acceleration of gravity since 1900, showing departures from Potsdam system.



At start, the silicon rod J rests with its metallic tip K in cone seat L attached to vacuum chamber. When catch D is opened, spring E gives B a slight push, separating it from bar J, which then floats free inside the vacuum chamber. Carriage is brought to smooth stop when plunger F enters dashpot G.

ACCELERATION *continued*

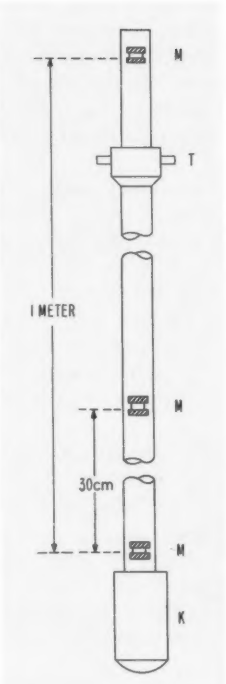
Initially, the rod rests vertically on a special bearing surface at the bottom of the chamber. To start the experiment, a latch is released, permitting carriage and chamber to fall. Just after this, a spring gives the carriage a small extra push downwards. This sends the vacuum chamber down and away from the rod, which then falls freely. The motion of the carriage is guided by rails.

The value of g varies not only with latitude and longitude (primarily the former), but also with altitude. Thus, in the 1 meter through which the rod dropped (distance between first and third holes) the value of g increased by roughly 3 parts in 10 million. This variation was, of course, taken into account in calculating g from the time and distance measurements. Also, it was desired to state the value of g at the level of the floor of the site, so that allowance had to be made for the change in g in going from the effective altitude of the experimental setup down to the floor.

It should be noted that "acceleration of gravity" is used here in its customary sense: namely, the acceleration produced in small bodies (that is, small compared to the earth) near the earth's surface by the resultant of the force of gravity and the inertial (centrifugal) force due to the earth's rotation.

[1] A preliminary summary is given in: **Absolute value of g at the National Bureau of Standards**, by D. R. Tate, J. Res. NBS **70C** (Engr. and Instr.), 149 (April–June 1966). A detailed report is in preparation.

[2] One milligal is one-thousandth of a gal (named for Galileo), a gal being an acceleration of 1 cm/s². One milligal is approximately 1 part in a million of the value of **g**.



Fused-silica bar used in free-fall gravity measurement. M: three holes bounded by metal knife edges. T: upper alinement bushing for rotational orientation of rod (not in contact at time of release). K: metallic tip with spherical segment which rests in cone seat until time of release.

TUNGSTEN FILAMENT LAMP *continued*

standards of luminous intensity, spectral radiance, and spectral irradiance.

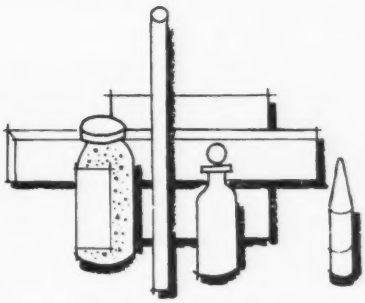
The new lamp standards are commercial projection-type tubular-bulb lamps having C–13 type coiled filaments and may be operated on either alternating or direct current. The useful calibration life (50 hours for 1 percent change) for the lamps is somewhat shorter than for the previous standards. However, the new lamps have an estimated overall accuracy of ± 1 percent and operate at color temperatures between 2700 and 2850 °K.

The new standards are of three sizes: 100-, 500-, and 1000-watt. They were selected for the absence of significant optical or mechanical defects, seasoned, marked for orientation, and calibrated for the density of radiant flux at 1 and 2 meters in the specified direction. For best operation the lamps are operated in a large blackened chamber or small unlighted room.

[1] W. W. Coblentz, Bull. BS **11**, 471 (1913), also BS Sci. Pap. **16**, 701 (1920).

New tungsten-filament lamp standards recently adopted by NBS have increased the accuracy and range of irradiance measurements beyond those possible with the previously used carbon filament lamps. The blackbody (center) is used to calibrate the lamps.

STANDARD REFERENCE MATERIALS



The NBS Office of Standard Reference Materials has prepared and certified new standard reference materials of beryllium-copper alloys, plastic fading chip, and limestone. Developed to meet the critical needs of science and industry in research, production control, and customer acceptance evaluations, these standards will be used for calibrating measurement equipment or measurement systems in the purchaser's laboratories. The new standard reference materials will be added to the more than 600 others supplied by the Office of Standard Reference Materials for use in calibrating spectrometers, temperature measuring equipment, viscometers, and other apparatus used to measure or determine radioactivity, isotope ratios of elements, dielectric properties, particle size, and the constituents of chemical compounds and metal alloys.[1]

Beryllium-Copper

Three new beryllium-copper standards became available with a provisional certificate December 19, 1966. In preparation for nearly 2 years, these standard materials were developed in cooperation with representatives of the electrical, electronics, and aerospace industries of the Nation to meet the needs of these industries for analytical reference materials.

The unique properties of the beryllium-copper alloys have led to their widespread use in electronic devices, instrumentation, welding, nonsparking safety tools, and in the specialized devices of almost every military, oceanographic, and aerospace system. Thousands of computer parts are made from these alloys including contact springs, connectors, bus systems, and like components of microminiaturized devices in which high reliability must be achieved.

The tolerances for variation in properties, many of which are composition dependent, are quite severe. The three new standard reference materials are NBS Standard Nos. 1121, 1122, and 1123 (in wrought form) and C1121, C1122, and C1123 (in chill-cast form), and correspond to CABRA alloys 165–170, 25–172, and 10–175, respectively. They will enable the production of off-specification material to be minimized in an industry which produces about $50 million worth of production material annually and which is growing at the rate of about 15 percent each year.

The material for each standard was melted and cast at the Beryllium Corp. plant, Reading, Pa. Homogeneity testing and analyses were made by the NBS Analytical Chemisty Division, the Micro Switch Division of Honeywell, Inc., the Beryllium Corp., and the Brush Beryllium Corp., Alloy Products Division.

These new materials provide a range of chemical compositions encompassing the beryllium-copper alloys in general commercial usage. In the form of wrought discs, 1¼ in. in diameter by ¾ in. thickness, and chill cast squares, 1¼ by 1¼ by ¾ in. thick, they are intended primarily for calibrating optical emission and x-ray spectrometric methods of analysis. Cross-sectional millings may be taken from the discs for calibrating the various solution methods of analysis. The beryllium-copper standards, each supplied with a certificate showing its chemical composition, cost $45 per unit.[2]

Light-Sensitive Plastic Chips

The stability of color and transparency are very important in plastics and textiles. These materials and their coloring agents are under continual testing in order to improve stability and to control quality for such uses as automobile upholstery, plastic building materials, and decorative materials.

Natural light and weathering are not completely reproducible and are slow to produce changes in a specimen. Thus materials calibrated against a standard source by a prescribed procedure have been needed to provide a standard reference material which everyone could use.

Poly (methyl methacrylate) plates containing a dye, Solvent Yellow 33—color index 47,000, have been calibrated at NBS with respect to fading of the dye by expo-

continued

REFERENCE MATERIALS *continued*

sure to carbon-arc radiation. Values of the transmittance of the plates at two wavelengths, 418 and 420 nanometers (millimicrons), were determined as a function of exposure, and a set of calibration curves for fading were prepared.

The fading chips constitute two new standard materials, designated NBS Standard Nos. 702 and 703. These standards were certified in November 1966 for use in the control and comparison of artificial fading and weathering apparatus. They are sold in sets of five chips with a Certificate of Calibration, including fading curves, for $15.50 per set.[2] They complement the opaque light-sensitive paper standards (NBS Standard Nos. 700a and 701a) for evaluating light dosage in light and exposure testing and in artificial weathering tests.

Limestone

Limestone is of major importance to the steel, glass, cement, building, and chemical industries and to agriculture as one of industry's essential low-cost raw materials. The basic oxygen process of steelmaking, only a developmental process a decade ago, is a major steelmaking process today, accounting for at least 25 percent of the more than 130 million ingot tons produced in the United States last year. More than half of the flux requirements of the industry are for this new process which has doubled its requirements for lime in the past 5 years. Relatively severe tolerances for chemical composition must be met. These require accurately calibrated methods of analysis.

To supply present day needs, two limestone standards are being prepared that are representative of the two major types of limestone. The first, designated NBS Standard No. 1b, an argillaceous stone, was certified November 8, 1966, as a renewal for No. 1a and costs $12 for a unit weighing approximately 50 grams.[2] A dolomitic limestone, NBS Standard No. 88a, is being prepared as a renewal of No. 88. Certification is expected to be completed by April 1, 1967. These standards will provide reference points for the analysis of limestones and are expected to be adequate for needs foreseen over the next 5 years or more.

New Publications

The NBS Miscellaneous Publication 260 Series was started to provide interested groups participating in the Standard Reference Materials Program with detailed information on specific aspects of the program. New publications in the series include: [3]

Misc. Publ. 260–11, "Standard Reference Material: Viscosity of a Standard Lead-Silica Glass," by A. Napolitano and E. G. Hawkins. 24 pages, 6 figures (Nov. 7, 1966). Price 25 cents.

Misc. Publ. 260–12, "Standard Reference Material: Homogeneity Characterization of NBS Spectrometric Standards III: White Cast Iron and Stainless Steel Powder Compact," by H. Yakowitz, D. L. Vieth, and R. E. Michaelis. 13 pages, 4 figures (Sept. 19, 1966). Price 20 cents.

Misc. Publ. 260–14, "Standard Reference Material: Determination of Oxygen in Ferrous Materials NBS Standard Nos. 1090, 1091, and 1092," by Oscar Menis and J. T. Sterling. 26 pages, 8 figures (Sept. 23, 1966). Price 30 cents.

Miscellaneous Publication 260–11 outlines details of the procedures used by NBS and seven other laboratories in measuring the viscosity of a lead-silica glass in the range of 10^2 to 10^{15} poises (in this range temperature varies from 1350–400 °C). Measurements were made by the rotating cylinder, restrained sphere, fiber-elongation, and beam-bending methods. The results presented in the report are critically evaluated.[4]

A continuation of the NBS efforts to characterize metal materials as to their suitability for calibrating microanalytical techniques is described in Miscellaneous Publication 260–12. The work was intended to test the usefulness of a chill-cast white cast iron and a compacted stainless steel powder in calibrating the solids mass spectrometer and the electron probe microanalyzer. It was concluded, from electron probe microanalysis and optical metallography, that the materials are not suitable for calibrating in microanalytical techniques although they are useful for such macroanalytical techniques as optical emission and x-ray spectrochemical analysis.

The methods that were used to determine the homogeneity and oxygen values of three new standard reference materials certified for oxygen content only are described in Miscellaneous Publication 260–14. The analyses were made by two different vacuum fusion procedures—a manometric measurement procedure in which the carbon monoxide from the sample was converted to carbon dioxide by copper oxide and the gases frozen differentially, and a direct infrared measurement of the carbon monoxide evolved. Additional values were obtained by utilizing an inert-gas fusion method. Data are also given for ingot iron, vacuum melted iron, and a chromium stainless steel (AISI Type 431) as reported by 18 cooperating laboratories.

[1] For a complete list of Standard Reference Materials available from NBS, see **Standard Reference Materials: Catalog and Price List of Standard Materials Issued by the National Bureau of Standards,** NBS Misc. Publ. 260, for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for 45 cents. Quarterly insert sheets which up-date Misc. Publ. 260 are supplied on request.

[2] These standards may be purchased for the price indicated from the Office of Standard Reference Materials, National Bureau of Standards, Washington, D.C. 20234.

[3] For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for the price indicated.

[4] See **Range of glass viscosity measurements extended,** NBS Tech. News Bull. **50,** No. 7, 106–107 (July 1966).

NSRDS NEWS

This column regularly reports significant developments in the program of the National Standard Reference Data System. The NSRDS was established in 1963 by the President's Office of Science and Technology to make critically evaluated data in the physical sciences available to science and technology on a national basis. The System is administered and coordinated by the National Bureau of Standards through the NBS Office of Standard Reference Data, located in the Administration Building at the NBS Gaithersburg Laboratories.

New Data Center

Since World War II, a wealth of information on electrolytic solutions has accumulated at such a rate that critical evaluations of the data have seriously lagged behind. Because of the importance of these data to science and industry, the National Bureau of Standards has recently established the Data Center for Thermodynamic and Transport Properties of Aqueous Solutions of Electrolytes within the Electrochemical Section of the NBS Electricity Division. Under the direction of Walter J. Hamer, Chief of the Section, the Center will compile and critically evaluate data on the properties of aqueous solutions of electrolytes.

Thermodynamic and transport properties of electrolytic solutions are important to the understanding and evaluation of such scientific and industrial processes as: (1) Electrode processes considered for the construction of dry cells, storage batteries, or fuel cells; (2) electrolytic processes used in the industrial production of hydrogen, deuterium, chlorine, and caustic soda, or the electrowinning or purification of metals; (3) reactions encountered in galvanic corrosion and commercial electroplating; (4) reactions used in chemical analysis; (5) reactions used in inorganic synthesis; and (6) general interpretations of the chemistry of the elements.

The compilation and critical evaluation activity of the Center may be divided into three branches. The first branch will work with data on the standard electrode potentials of the elements and the standard oxidation-reduction potentials of chemical processes from the freezing to the boiling point of the aqueous medium. These potentials will be related to the National Standard of electromotive force (or voltage) maintained by the Electrochemical Section. The potentials will also be critically evaluated for utilization in the determination of the Gibbs (free) energy of formation and related thermodynamic data for compounds.

The second branch will deal mainly with data on activities and activity coefficients of electrolytic solutions. Activity coefficients give a measure of the deviations of solutions from ideality and include the magnitude of all effects that lead to these deviations. Activity coefficients also are utilized in arriving at the standard values for the potentials covered by the first branch. These coefficients are also important in evaluating rate and equilibrium constants for chemical processes and electrolytic dissociation. Emphasis is presently being given to potassium and sodium chloride which are generally used as standards for the activity coefficients of other substances.

The third branch will work with data on the electrolytic conductivity of aqueous solutions and the transference numbers and mobilities of the ions in such solutions. The only extensive collection in English of "authoritative" data on the conductivity of electrolytic solutions and transference numbers is contained in Volumes V and VI of the *International Critical Tables* published in 1929. The data included in these tables were based on 1,093 references; the Center has collected an additional 3,576 references to data published since then. These data are being interpreted in terms of the modern conductivity theories of Fuoss and Onsager. A computer is utilized to obtain the best least-square fit to theoretical equations expressing the conductance as a function of concentration.

Ultimately, data on densities, viscosities, and heats of dilution for aqueous solutions of electrolytes will be covered by this Center.

Data on nonaqueous systems and molten-salt media are being supplied by two adjunct centers: Dr. Loren Hepler of the Carnegie Institute of Technology supplies data on nonaqueous systems and Dr. George Janz of the Rensselaer Polytechnic Institute supplies data on molten salts.

Evaluating the Surface Tension of Pure Liquids

Joseph J. Jasper, Professor Emeritus of Chemistry at Wayne State University, Detroit, Mich., is embarking on a project to evaluate the surface tension of pure substances which are liquid at ordinary temperatures. He will make a comprehensive survey of the literature to un-

continued

cover relevant data and will review them critically in terms of methodology, precision, accuracy, and related factors.

The project will complement an existing project on the surface tensions of fused salts which is now being carried out at Rensselaer Polytechnic Institute under George Janz.

Pennsylvania State University Cooperates on Crystal Data

For some time, Pennsylvania State University has been engaged in an effort to put the Powder Diffraction file of the American Society for Testing and Materials into computer-readable form. Now under contract with the NBS Office of Standard Reference Data, the University will undertake an effort to coordinate the single-crystal data of Donnay's *Crystal Data Determinative Tables* with the ASTM file. As previously reported (*NSRDS News*, TNB August 1966), the Office of Standard Reference Data is sponsoring the reissue of Donnay's tables by means of computer-controlled typesetting. A byproduct of this effort is a magnetic tape containing the entire information of the tables.

The NBS-Pennsylvania State University project will put the two files into formats which are compatible, so that intercomparison of data becomes possible, and which at the same time are suitable for automatic searching of tapes in response to questions fed into the computer. Hopefully, the resulting crystal data file will serve as a test case for computer storage, retrieval, printing, and updating of data files.

High Temperature Properties and Decomposition of Inorganic Salts Part 1. Sulfates

In the last generation, inorganic salts, particularly in the liquid state, have assumed increasing importance in a variety of applications. They are useful as reaction media, in metallurgical processes, and in electrochemical power sources such as fuel cells and thermal batteries.

Experimentalists and theorists have found molten salts an interesting subject for study since these ionic fluids offer an unusual opportunity for the study of short-range ionic interactions in the liquid state.

So far, attention in this field has largely been focused on the halides since their stability at high temperatures is well known. The only decomposition which they can undergo is dissociation into the elements. The extent of this dissociation can be easily calculated from existing thermodynamic compilations.

For most inorganic salts the situation is more complicated. In many cases the decomposition reactions are not well defined and high-temperature thermodynamic and kinetic data are either lacking or scattered through the literature. Thus, although the study of many salts would undoubtedly prove interesting and useful, they have received little attention at high temperatures because in many cases not even the range of thermal stability is known.

High Temperature Properties and Decomposition of Inorganic Salts, Part 1, Sulfates,[1] has been published as NSRDS–NBS–7. This publication is part of a series of critically evaluated compilations providing in concise form thermodynamic and kinetic data relevant to the high-temperature behavior of important classes of inorganic salts. For the present, the compilations in this series are restricted to anhydrous compounds with monatomic cations and oxyanions containing one element besides oxygen. Each volume in this series will deal with compounds of one anion. NSRDS–NBS–7 is the first in the series and deals with sulfates.

Thermodynamic variables included in NSRDS–NBS–7 are:

(a) Phase transition temperatures above 298.15 °K, except those at high pressure, together with the corresponding enthalpies and entropies.

(b) Equilibrium constants and decomposition pressures, as well as relevant free-energy functions from 298.15 °K to as high a temperature as data exist. ΔHf and S° values of reactants and products at 298.15 °K from which the above functions are calculated are also given.

(c) Densities at 298.15 °K and above.

Kinetic data which have been included are:

Qualitative and quantitative information on the kinetics of thermal decomposition.

Part 2 of this series, Carbonates, is due for publication in 1967. This will be followed by a critical compilation on halides.

Thermal Conductivity of Selected Materials

Thermal Conductivity of Selected Materials,[1] by R. W. Powell, C. Y. Ho, and P. E. Liley of the Thermophysical Properties Research Center, Purdue University, has been published as NSRDS–NBS–8. This compilation consists of the critical evaluation and analysis of the available thermal conductivity data on 11 metals and 9 nonmetals mainly for the solid state, on 7 fluids for both the liquid and gaseous states, and on 2 for liquid state only. The materials studied were selected primarily for their potential applicability as reference standards or because of their technical importance.

The metals included in this compilation are aluminum (solid and liquid state), copper, gold, iron (Armco and pure), manganin, mercury (liquid state), platinum, platinum alloyed with 40 percent rhodium, silver, and tungsten.

The nonmetallic solids treated include aluminum oxide, beryllium oxide, Corning code 7740 glass, diamond, magnesium oxide, ceramic code 9606 glass, quartz, thorium dioxide, and titanium dioxide.

Data in the literature for the following substances in both liquid and gaseous state were examined and evaluated in this compilation: argon, carbon tetrachloride, di-

Mrs. Anne Marie O'Toole operates the console used in the Electrochemical Section to measure the electromotive force of galvanic cells and standard cells.

phenyl, helium, nitrogen, m-terphenyl, p-terphenyl, toluene, and water.

Microwave Spectral Tables

NBS Monograph 70 is a five-volume set of *Microwave Spectral Tables* compiled by members of the NBS Radio Standards Laboratory at Boulder, Colo. Volume I, Diatomic Molecules, and Volume II, Line Strengths of Asymmetric Rotors, appeared in December 1964. Although both volumes were written before the NSRDS program in atomic and molecular properties became active, the Office of Standard Reference Data has encouraged efforts to complete the series. Monograph 70 is expected to be of considerable use to researchers in the field of microwave spectroscopy and to others who are exploring the use of microwave techniques for chemical analysis.

Volume III, *Microwave Spectral Tables*, Polyatomic Molecules With Internal Rotation, by P. F. Wacker, M. S. Cord, D. G. Burkhard, J. D. Peterson, and R. F. Kukol, has now been completed. Volumes IV and V will appear shortly after Volume III. Volume IV is entitled Spectra of Polyatomic Molecules Not Capable of Exhibiting Internal Rotation, and Volume V lists spectral lines according to frequency and will serve as a line index for the whole series. For continuity and consistency, these volumes have been made part of the Monograph 70 series, and not a formal part of the NSRDS publication program.

The plans of the Office of Standard Reference Data include active continuation of efforts to review, evaluate, select, and publish microwave spectral tables as part of the NBS contribution to the NSRDS program.

Extension of X-Ray Cross-Section Data Down to 1 keV

X-Ray Attenuation Coefficient From 10 keV to 100 MeV, by Gladys White Grodstein, NBS Circular 583 (April 30, 1957)[1] is a tabulation of x-ray cross-section data for energies in the 10 keV to 100 MeV range. For lower energies, however, no generally accepted tabulation exists. As a result, a number of independent low-energy tabulations are in circulation, a factor which has led to difficulties in the exchange of information between laboratories.

An intensive effort, making optimum use of present computer capabilities, is underway to compile tables over the range 1 keV to 1 MeV using the best experimental and theoretical knowledge. This effort, sponsored by the Defense Atomic Support Agency, is being conducted at the Lawrence Radiation Laboratory, Livermore, Calif., under the direction of W. H. McMaster. J. H. Hubbell, of the NBS Radiation Physics Division, currently engaged in overlapping and higher energy x-ray tabulations under NSRDS sponsorship, is serving as a consultant and evaluator on the project. This DASA–LRL–NBS collaboration will provide a much wider acceptance of the tables and will present the possibility of using the numbers in whole or in part to provide a low-energy extension of present NBS tables sooner than could be done otherwise.

[1] For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for the price indicated: NSRDS–NBS–7—35 cents, NSRDS–NBS–8—$1.00, NBS Circ. 583—25 cents.

PUBLICATIONS *of the National Bureau of Standards*

PERIODICALS

Technical News Bulletin, Volume **51**, No. 2, February 1967. 15 cents. Annual subscription: $1.50. 75 cents additional for foreign mailing. Available on a 1-, 2-, or 3-year subscription basis.

Journal of Research of the National Bureau of Standards

Section A. Physics and Chemistry. Issued six times a year. Annual subscription: Domestic, $5; foreign, $6. Single copy, $1.00.

Section B. Mathematics and Mathematical Physics. Issued quarterly. Annual subscription: Domestic, $2.25; foreign, $2.75. Single copy, 75 cents.

Section C. Engineering and Instrumentation. Issued quarterly. Annual subscription: Domestic, $2.75; foreign, $3.50. Single copy, 75 cents.

CURRENT ISSUES OF THE JOURNAL OF RESEARCH

J. Res. NBS **71B** (*Math. and Math. Phys.*), No. 1 (Jan.–Mar. 1967), 75 cents.

Algorithms for frames and lineality spaces of cones. R. J. B. Wets and C. Witzgall.

The coefficients of the powers of a polynomial. M. Newman.

Stable evaluation of polynomials. C. Mesztenyi and C. Witzgall.

On involutions. O. Shisha and C. B. Mehr.

Minimum number of subsets to distinguish individual elements. P. R. Meyers.

E-transforms. F. M. Ragab.

Three observations on nonnegative matrices. A. J. Hoffman.

Additional remarks on a theorem of M. Riesz. J. M. Smith.

OTHER NBS PUBLICATIONS

Heat treatment and properties of iron and steel, T. G. Digges, S. J. Rosenberg, and G. W. Geil, Mono. 88 (November 1, 1966), 35 cents. (Supersedes Circ. 495 and Mono. 18).

The National Bureau of Standards 1966, Misc. Publ. 282 (Nov. 1966), 35 cents.

A grammar for component combination in chinese characters, B. K. Rankin, III, S. Siegel, A. McClelland, and J. L. Tan, Tech. Note 296 (Dec. 1966), 60 cents.

A new near-zone electric field-strength meter, F. M. Greene, Tech. Note 345 (Nov. 15, 1966), 35 cents.

Infrared reflectances of metals at cryogenic temperatures—a compilation from the literature, P. F. Dickson and M. C. Jones, Tech. Note 348 (Oct. 14, 1966), 40 cents.

The design and operation of a high voltage calibration facility, W. W. Scott, Jr., Tech. Note 349 (Nov. 10, 1966), 25 cents.

Radiochemical analysis: activation analysis, instrumentation, radiation techniques, and radioisotope techniques, July 1965 through June 1966, Ed. J. R. DeVoe, Tech. Note 404 (Sept. 30, 1966), $1.25.

PUBLICATIONS IN OTHER JOURNALS

This column lists all publications by the NBS staff, as soon after issuance as practical. For completeness, earlier references not previously reported may be included from time to time.

CHEMISTRY

Acidity functions for amphiprotic media, R. G. Bates, Book, Chemistry of Nonaqueous Solvents, **I**, Sect. III, 97–128 (Academic Press, Inc., New York, N.Y., 1966).

Approximate eigenfunctions of the Liouville operator in classical many-body systems, R. Zwanzig, Phys. Rev. **144**, No. 1, 170–177 (Apr. 8, 1966).

Collagen aggregation phenomena, J. M. Cassel, Biopolymers **4**, 989–997 (1966).

Crystal growth of bone mineral, W. E. Brown, Clin. Orthopaed **44**, 205–219 (1966).

Effect of certain crystalline substances on physical properties of elastomers. I. Stress-strain behavior, F. J. Linnig, E. J. Parks, and R. D. Stiehler, Rubber Chem. Technol. **39**, No. 4, Pt. 1, 1041–1052 (Sept. 1966).

Infrared spectra of hydroxyapatite, octacalcium phosphate and pyrolysed octacalcium phosphate, B. O. Fowler, E. C. Moreno, and W. E. Brown, Arch. Oral. Biol. **11**, 477–492 (1966).

Oxidation products in an oxygen-blown Kuwait asphalt, P. G. Campbell and J. R. Wright, I&EC Product Res. Devel. **5**, No. 4, 319–323 (Dec. 1966).

Proton broad-line NMR study of ($^2H_6$) dimethoxy (^{11}B) borane, T. C. Farrar, J. Cooper, and T. D. Coyle, Chem. Commun. **17**, 610–611 (1966).

Pyrolysis of vinyl and vinylidene fluoride polymers: Influence of prior gamma-irradiation, L. A. Wall, S. Straus, and R. E. Florin, J. Polymer Sci, **4**, Pt. A-1, 349–365 (1966).

Random-walk model of adsorption of a chain-polymer molecule on a long rigid-rod molecule, R. J. Rubin, J. Chem. Phys. **44**, No. 5, 2130–2138 (Mar. 1, 1966).

Rodlike behavior of poly(n-butyl)isocyanate from dielectric measurements, H. Yu, A. J. Bur, and L. J. Fetters, J. Chem. Phys. **44**, No. 7, 2568–2576 (Apr. 1, 1966).

Shear relaxation times of simple fluids, R. D. Mountain and R. Zwanzig, J. Chem. Phys. **44**, No. 7, 2777–2779 (April 1966).

Silicon-fluorine chemistry. II. Silicon-boron fluorides, P. L. Timms, T. O. Ehlert, J. L. Margrave, F. E. Brinckman, T. C. Farrar, and T. D. Coyle, J. Am. Chem. Soc. **87**, No. 17, 3819–3823 (September 1965).

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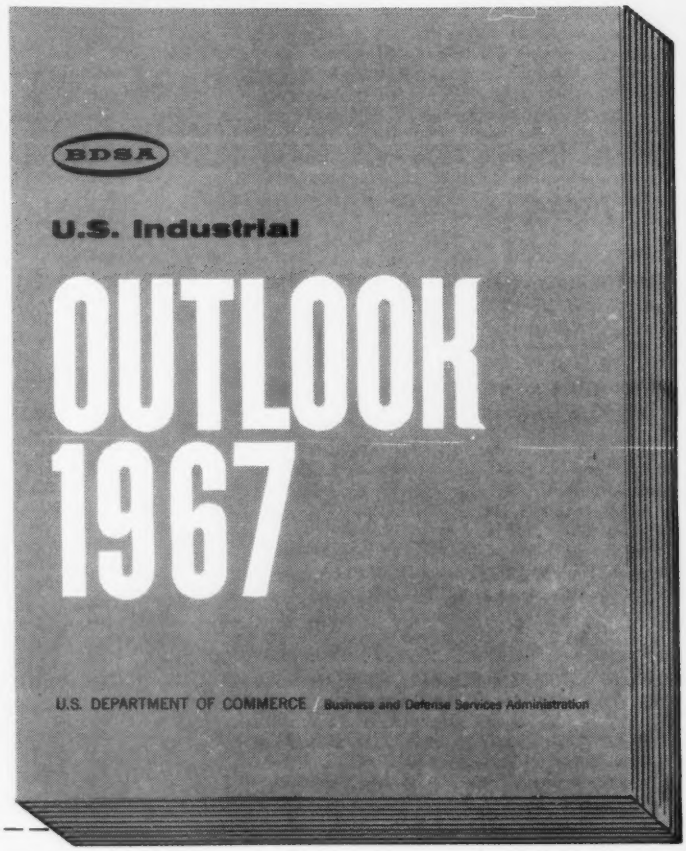

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